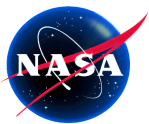


NEW MILLENNIUM PROGRAM

An Overview of NMP Code-Y Activities

Faiza Lansing

March 3, 2000

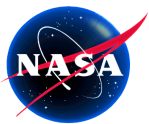


Purpose of Meeting



On February 4, 2000, F. Li had an informal discussions of with G. Asrar

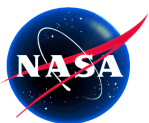
- Technology validation needs for Earth Science
- Describe updated New Millennium Program structure
- Recommended next steps



Challenges to New Millennium Program



- Improve cost-effectiveness of technology flight validation
 - Focus NMP investments on breakthrough technologies/risk reduction
 - ◊ Increased reliance on flights-of-opportunities
 - ◊ Focus on technology “pieces” requiring flight validation
- Deliver benefits to broad set of Earth Science measurements
 - Reduce cost/enable new capabilities
 - Align technology with science needs
- Enhance partnership for technology development/validation and accelerate technology infusion

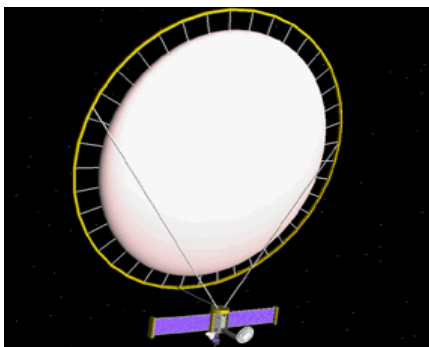


Technology Subsystem Themes

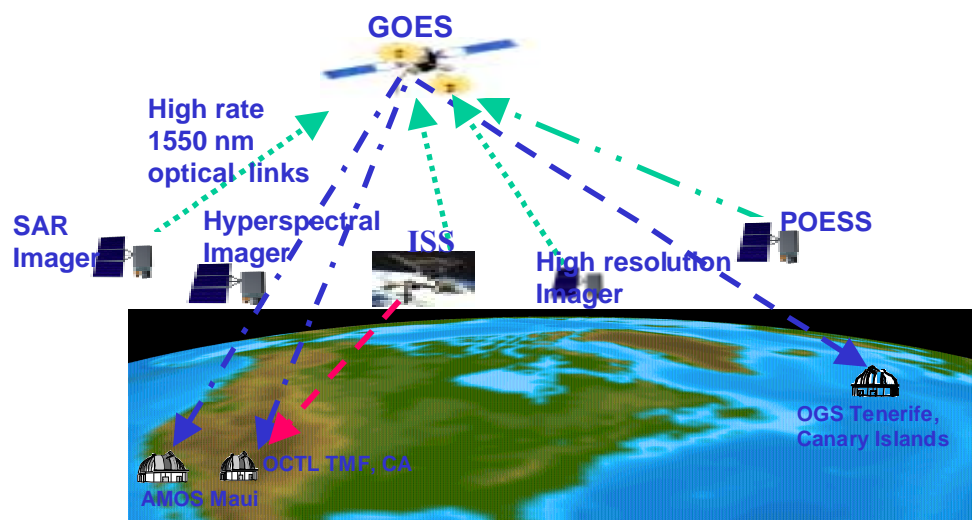
NMP

- Preliminary assessment of technology validation needs
- Recurring technology subsystem validation “themes”
- Technology themes benefit a broad set of Earth Science measurements.

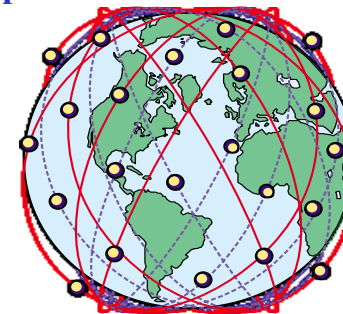
Deployable Light-Weight Microwave/ Milliwave Antennas



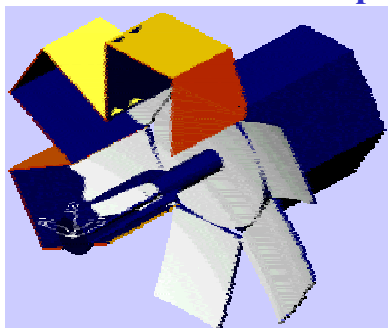
Ultra High Data Rate Communications



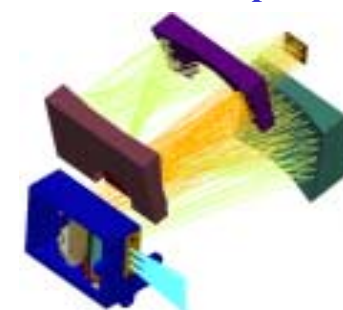
Intelligent Distributed Spacecraft Infrastructure

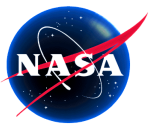


Light Weight Deployable UV/Visible/IR Telescope



High Performance Spectrometry





Updated New Millennium Program Structure Considerations

NMP

Balanced Mix of Breakthrough Subsystem/ Integrated System

- Incorporate testing of technology subsystems
 - Broad benefits to multiple measurement needs
 - Focus on validating the technology “pieces” where needed
- Sharpen criteria for integrated measurement system

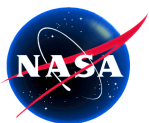
Stronger Reliance On Flights-of- Opportunity

- Minimize investments in “low tech”
- Broaden validation platform possibilities
 - Including Earth science missions

Updated NMP Structure

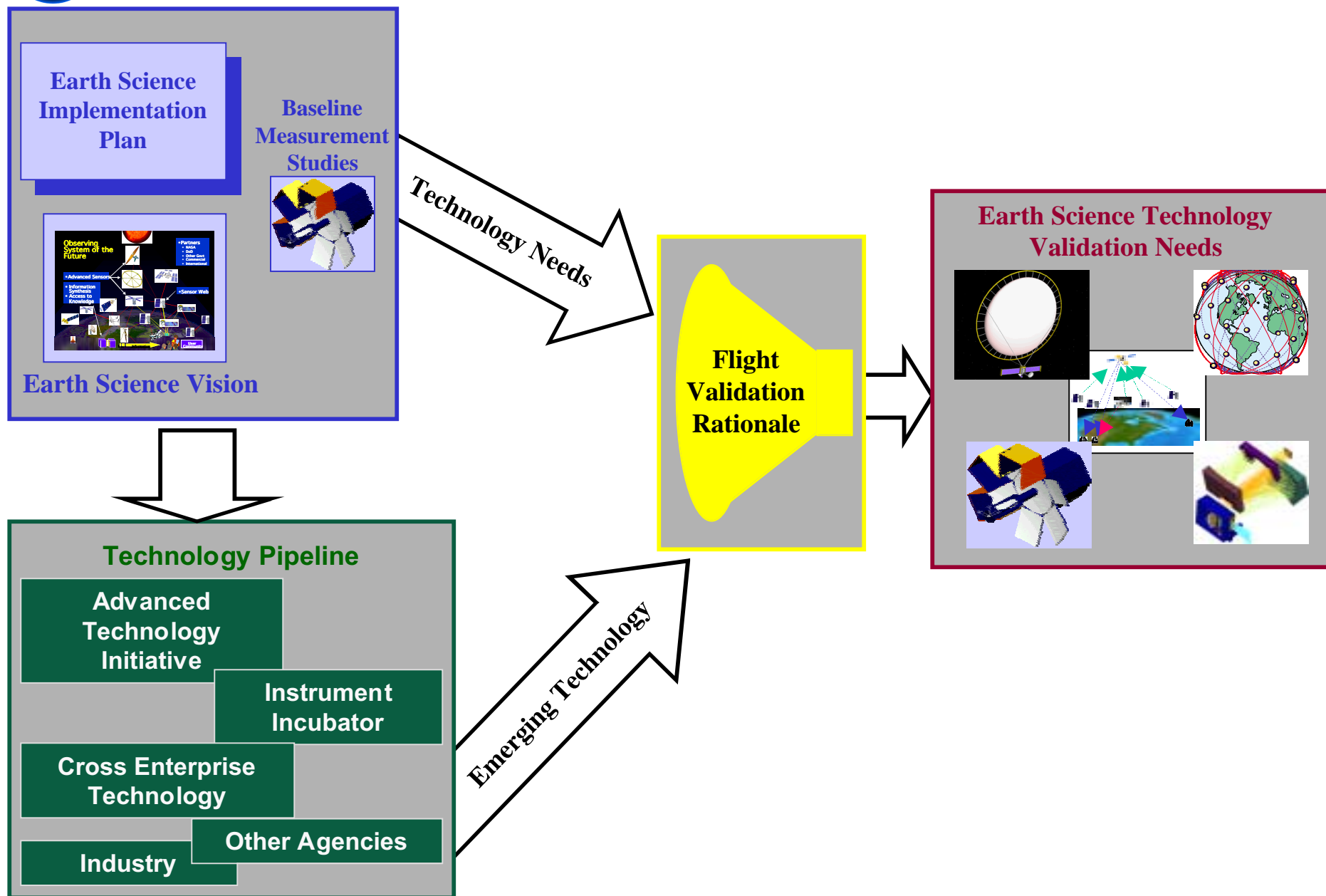
Enhanced Partnership

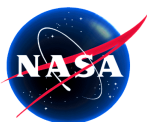
- Share technology development investment
- Share technology validation platforms
- Improve technology infusion targeting



Technology Validation Needs for Earth Science

NMP

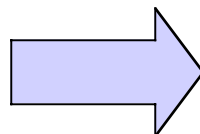




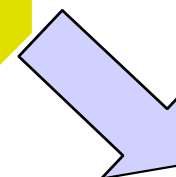
Technology Validation Needs from Science/Applications Plan



**Earth Science
Implementation
Plan**

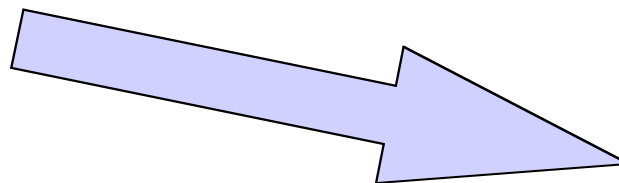
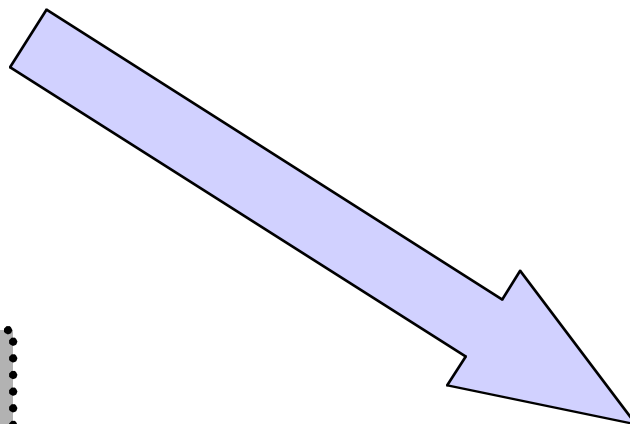


**Baseline
Measurement
Studies**



Earth Science Technology Needs Analysis

**Applications
Strategic Plan**



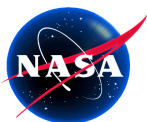
Environmental Prediction

Long Range Weather Prediction
Climate Prediction
Global Change
Global Air & Water Quality
Natural Hazards
Human Health
Global Air & Water Quality

Legend:
● = major overlap
○ = minor overlap

ESE Mission Scenario 2002-2010

Mission	Expected Launch Date	MEASUREMENT APPROACH	ENVIRONMENTAL PREDICTION
		A. Remote Sensing	B. Modeling
		1. Global Temperature	2. Global Precipitation
		3. Global Clouds	4. Global Wind
		5. Global Radiation	6. Global Air Quality
		7. Global Water Quality	8. Global Water Quantity
		9. Global Ecosystems	10. Global Human Health
		11. Global Air Quality	12. Global Water Quality
		13. Global Radiation	14. Global Wind
		15. Global Clouds	16. Global Precipitation
		17. Global Temperature	18. Global Air Quality
		19. Global Water Quality	20. Global Water Quantity
		21. Global Ecosystems	22. Global Human Health
		23. Global Air Quality	24. Global Water Quality
		25. Global Radiation	26. Global Wind
		27. Global Clouds	28. Global Precipitation
		29. Global Temperature	30. Global Air Quality
		31. Global Water Quality	32. Global Water Quantity
		33. Global Ecosystems	34. Global Human Health
		35. Global Air Quality	36. Global Water Quality
		37. Global Radiation	38. Global Wind
		39. Global Clouds	40. Global Precipitation
		41. Global Temperature	42. Global Air Quality
		43. Global Water Quality	44. Global Water Quantity
		45. Global Ecosystems	46. Global Human Health
		47. Global Air Quality	48. Global Water Quality
		49. Global Radiation	50. Global Wind
		51. Global Clouds	52. Global Precipitation
		53. Global Temperature	54. Global Air Quality
		55. Global Water Quality	56. Global Water Quantity
		57. Global Ecosystems	58. Global Human Health
		59. Global Air Quality	60. Global Water Quality
		61. Global Radiation	62. Global Wind
		63. Global Clouds	64. Global Precipitation
		65. Global Temperature	66. Global Air Quality
		67. Global Water Quality	68. Global Water Quantity
		69. Global Ecosystems	70. Global Human Health
		71. Global Air Quality	72. Global Water Quality
		73. Global Radiation	74. Global Wind
		75. Global Clouds	76. Global Precipitation
		77. Global Temperature	78. Global Air Quality
		79. Global Water Quality	80. Global Water Quantity
		81. Global Ecosystems	82. Global Human Health
		83. Global Air Quality	84. Global Water Quality
		85. Global Radiation	86. Global Wind
		87. Global Clouds	88. Global Precipitation
		89. Global Temperature	90. Global Air Quality
		91. Global Water Quality	92. Global Water Quantity
		93. Global Ecosystems	94. Global Human Health
		95. Global Air Quality	96. Global Water Quality
		97. Global Radiation	98. Global Wind
		99. Global Clouds	100. Global Precipitation
A. ESE Follow-On Missions (systematic measurements)			
EOS-1 Land Cover/Land Use Inventory Program	2005	X X X	
EOS-2 Climate Variability & Trend Mission	2006	X	X
EOS-3 Global Terrestrial & Oceanic Productivity Mission	2005	X	X
EOS-4 Total Solar Irradiance Monitoring Mission	2005	X X X X	
EOS-5 Ocean Surface Wind Measurement Program	2004		X
EOS-6 Ocean Surface Topography Mission	2009		X X
EOS-7 Stratospheric Composition Measurement Program	2008		X X X
EOS-8 Topography and Surface Change Mission	td	X	X X X
EOS-9 Global Precipitation Mission	2007	X X	
EOS-10 Polar Altimetry Mission	2010	X	X
B. Earth Probe Missions (exploratory & focussed process studies)			
Ex-1 Tropospheric Chemistry Research Mission(s)	2004		X
Ex-2 Aerosol Radiative Forcing Research Mission	td		X X
Ex-3 Cloud Radiation Feedback Research Mission	td		X X X
Ex-4 Soil Moisture & Ocean Salinity Observing Mission	td	X X	X X X
Ex-5 Time-Dependent Gravity Field Mapping Mission	td		X
Ex-6 Vegetation Recovery Mission	2008	X	X
Ex-7 Cold Land Processes Research Mission	td	X	X
C. Pre-Operational Instrument Development (new & better sensors)			
OP-1 Advanced Microwave Sounder	td		X
OP-2 Tropospheric Wind Sounder	2001		X
OP-3 GPS Constellation for Atmospheric Sounding	td		X
OP-4 Advanced Geostationary Sounder	td		X X
OP-5 Volcanic Ash & Gas Emission Mapping & Advanced Geolmager	td	X X X	X
OP-6 Special Event Imager	td	X X X	X
OP-7 Geostationary Lightning Mapper	td	X X X	X



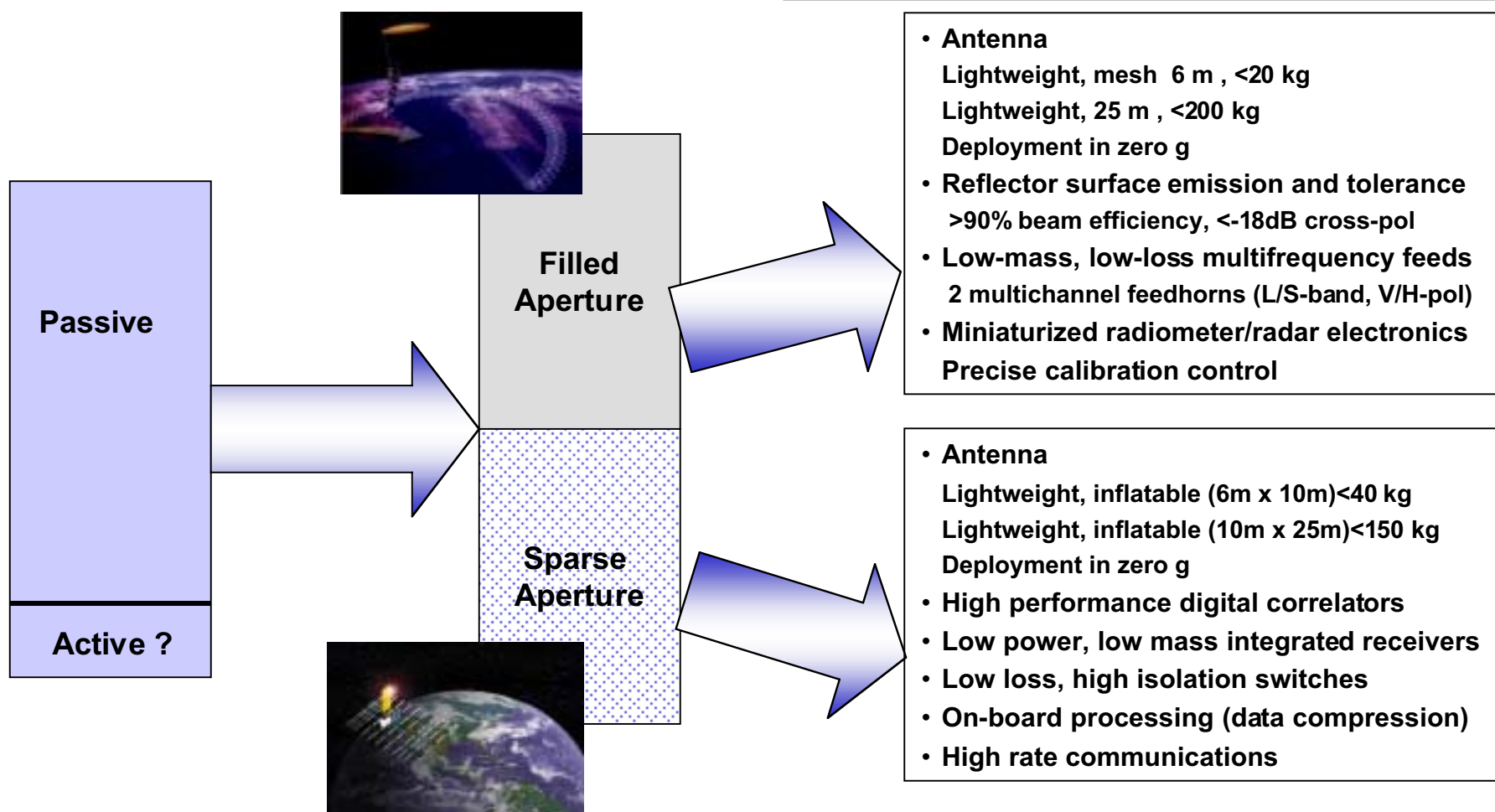
Preliminary Soil Moisture Technology Needs

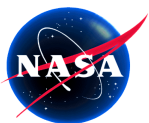
NMP

OBJECTIVE: Enable detection of measurement of volumetric moisture in the upper 5-10 cm of the soil with spatial resolution 10-30km and 2-3 day revisit time.

TECHNOLOGY CHALLENGE: Current concepts offer two competing instrument technology paths:

- Synthetic aperture radiometer with thinned antenna array
 - Real aperture radiometer with mesh antenna
- Both options require investments to answer technological readiness, risk of deployment, structural stability on orbit, and growth potential questions.





Soil Moisture Measurement: Technology Strategic Pathways

NMP

- Near-term Science Measurement Pathway: 30-40km resolution
: Passive remote sensing

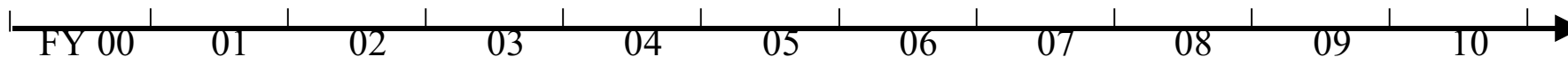
Synthetic Aperture Radiometer



Mesh Antenna



Soil Moisture



- Enhanced Science Measurement Pathway: ~10km resolution
: Active/Passive remote sensing

Inflatable Antenna Technology



Formation Flying



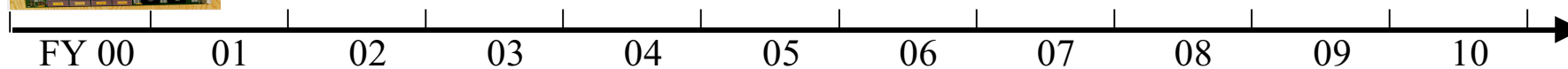
Digital Correlators



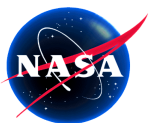
Flight Validation



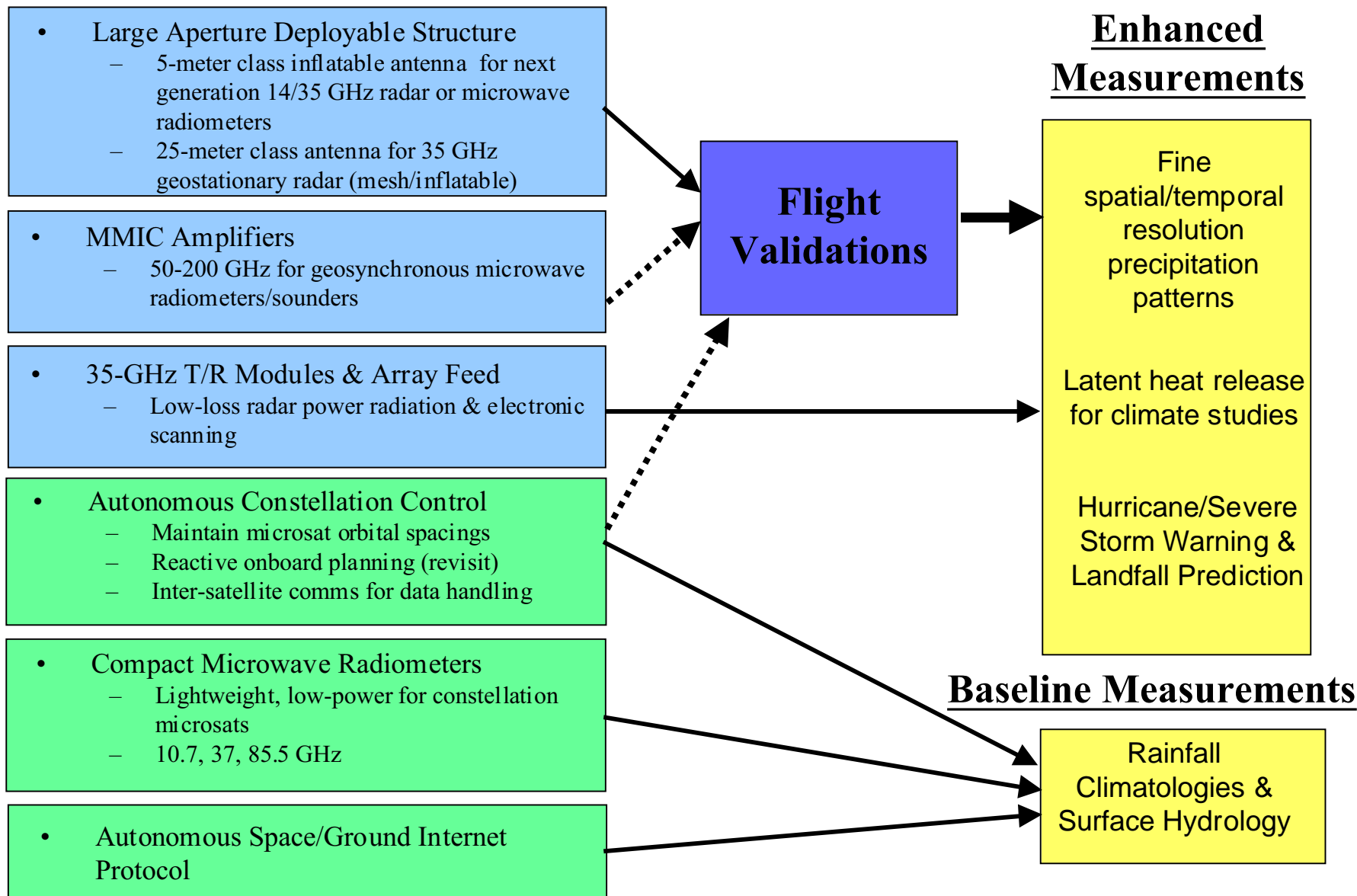
Enhanced Soil Moisture Measurement

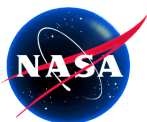


Nominal Time Frame



Preliminary Technology Needs for Global Precipitation Measurement Series





Integrated Technology Plan To Enable Global Precipitation Measurements

NMP

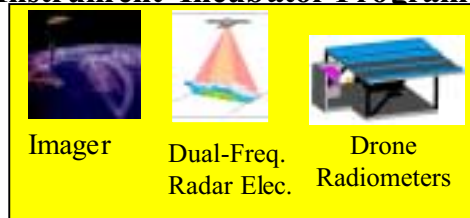
Objective:

- Provide systematic estimation of global precipitation with three hours or less sampling interval
 - Improved weather forecasting
 - Global water cycle understanding

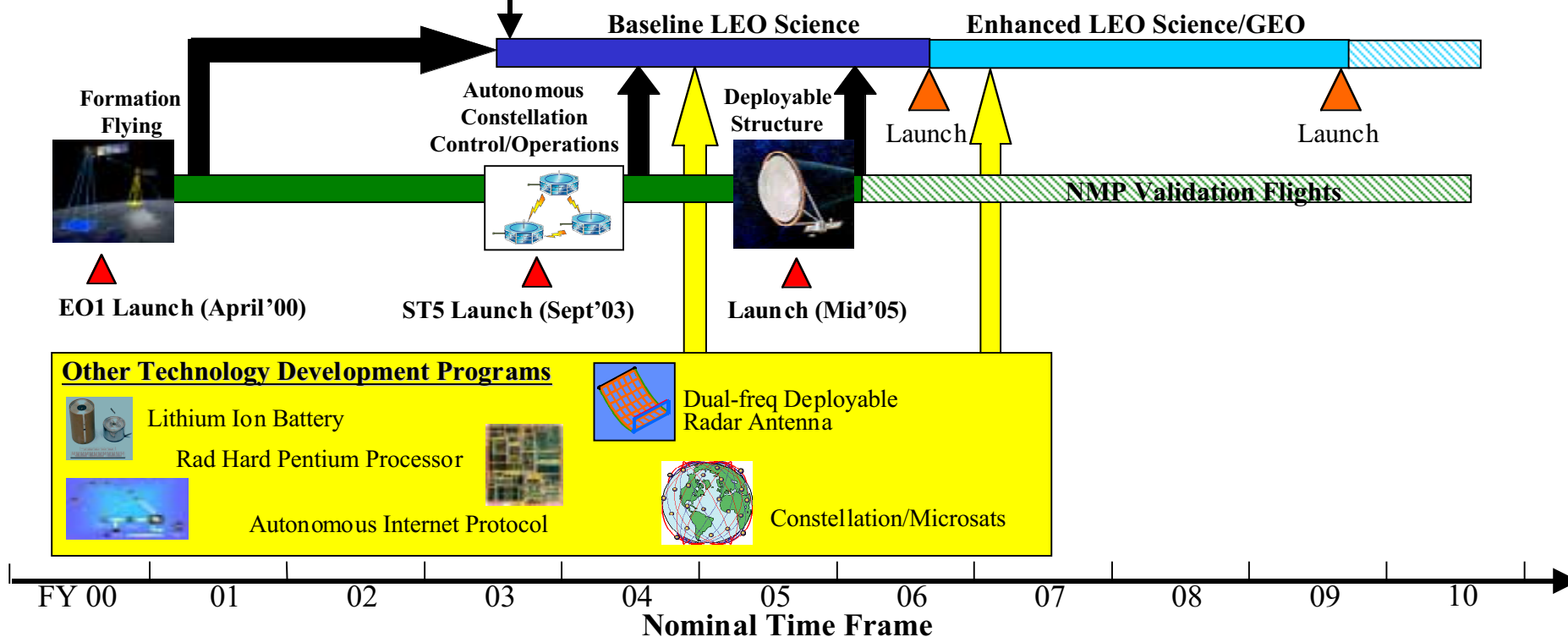
Technology Challenges:

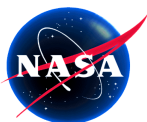
- Integrated Observatory with autonomous constellation control and operations
- Optimized inter-satellite communications for data handling and downlink
- Large aperture deployable structure
- Large aperture radiometers
- Autonomous space/ground internet protocol

Instrument Incubator Program



Global Precipitation Observation Strategy





Tropospheric Ozone Measurement: Preliminary Technology Needs

NMP

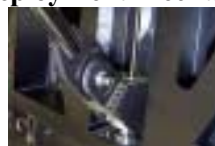
UV DIAL: 308/320 nm @ 10Hz; O₃ vertical resolution 2.0-2.5 km in troposphere;
horizontal resolution 100 km; IFOV < 100 m

Diode-pumped Laser Transmitter (UV)



Measurement requirements: 500mJ, 308/320 nm @ 10Hz
Current capability: 130mJ, 308/320 nm @ 10Hz

Precision Latch & Hinge Deployment Mechanisms

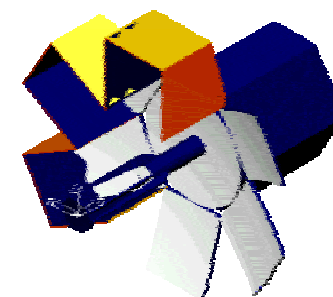


Measurement requirement: repeatability reliability,
one-time operation

Composite Mirror Panels



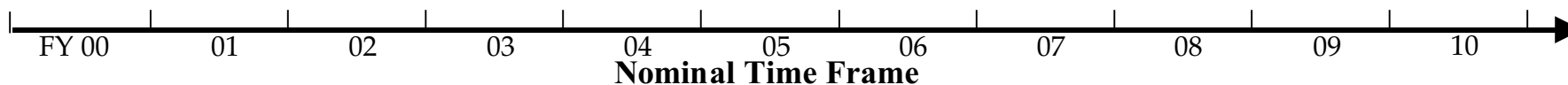
Measurement requirement: 3m aperture

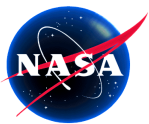


NMP - flight validation

Validation Mission

Tropospheric Ozone Measurement



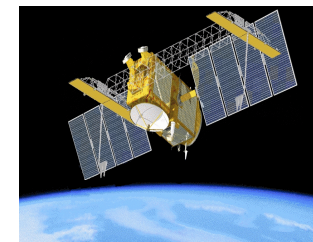


Preliminary Example of Flight Validation Candidate

NMP

Enhanced Ocean Topography Measurement

- Flight Validation Candidate: Wide swath altimetry
Precision stable structure
Delay/Doppler altimeter



IIP - Wide swath altimeter

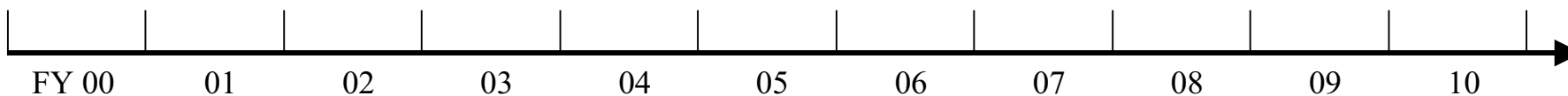
IIP - Delay Doppler altimeter

NMP - flight demo

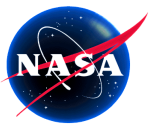
Enhanced Mission

Launch

Validation Launch



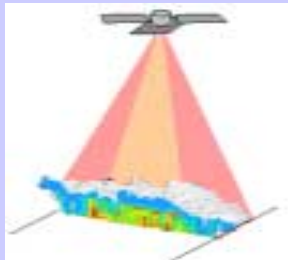
- Flight validation of Integrated Measurement System
 - Ensure critical ocean topography measurement continuity
 - Paradigm shift in measurement approach



Potential IIP Flight Validation Candidates



A Second generation Spaceborne Precipitation Radar (PR-2)



Technology area

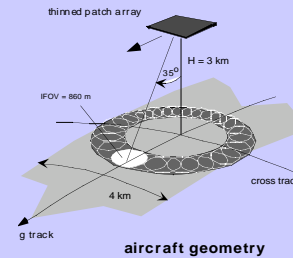
5.3 meter dual-frequency (13.6 & 35 Ghz) lightweight (100 Kg) inflatable antenna

Flight Validation Rationale

Test the stability and antenna pattern of a large, light weight inflatable structure for 35 Ghz frequency, 600 KM swath at 2 Km resolution.

Inflatable Antenna

Two Dimensional Synthetic Aperture Radiometer for Microwave Remote Sensing from Space



Technology area

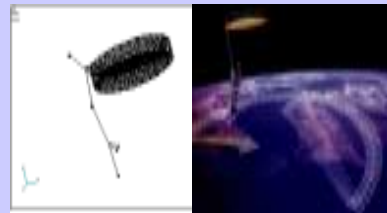
6X10 meter deployable thin array antenna
Small digital correlators

Flight Validation Rationale

Validate the thin array antenna concept
Verify structural and thermal stability
Verify two-dimensional aperture synthesis concept

Large/lightweight Deployable Antenna

Spaceborne Microwave Instrument for High Resolution Remote Sensing Using a Large Aperture Mesh Antenna



Technology area

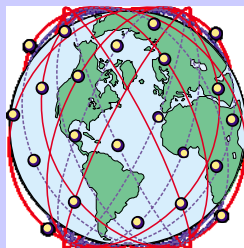
6-meter aperture deployable mesh reflector

Flight Validation Rationale

Validate stability of mesh reflector

Deployable Mesh Antenna

Active Tropospheric Ozone and Moisture Sounder (ATOMS)



Technology area

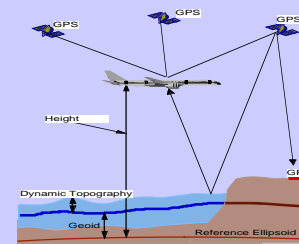
10,22, and 183 GHz links for moisture sounding from 0~20 km
110 and 165 GHz links for ozone sounding from 8km - ~60 km

Flight Validation Rationale

Validate control infrastructure needed for monitoring, controlling, and orbit maintenance of a constellation of small satellites

Constellation of Small Satellites

GPS-Based Oceanographic and Atmospheric Low Earth Orbiting Sensor (GOALS)



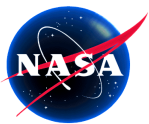
Technology area

Performing surface altimetry using GPS reflections

Flight Validation Rationale

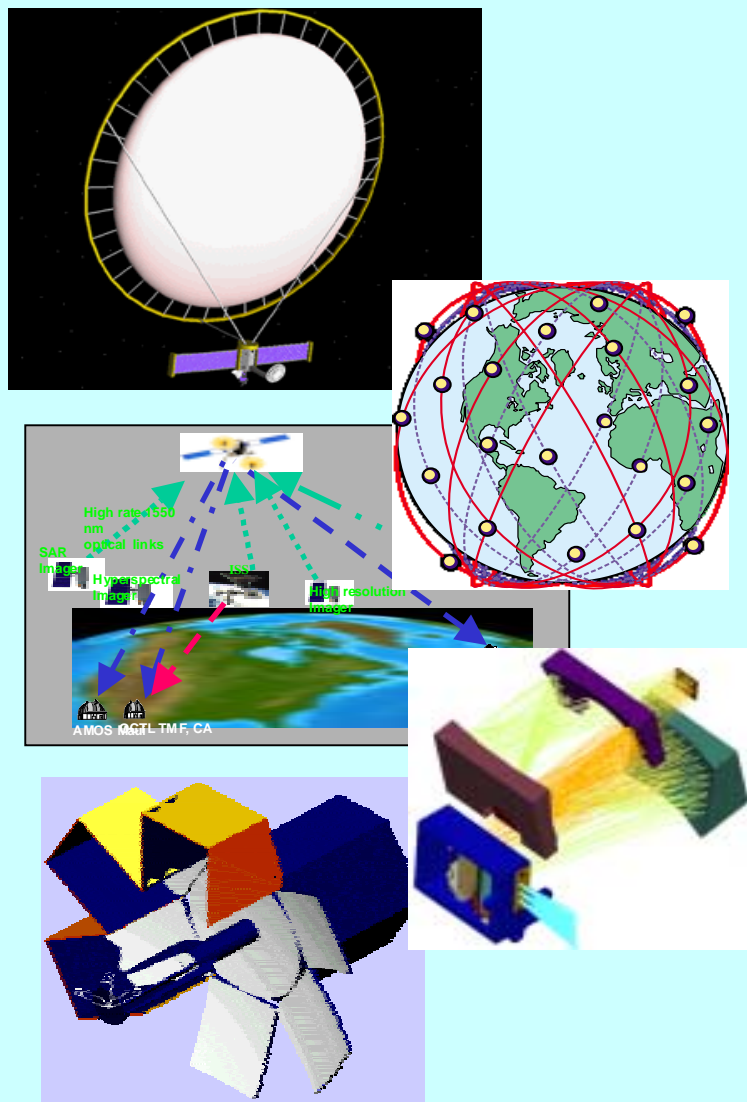
Validate new measurement concept of an on-going measurement

Measurement Technique Using Constellation of Satellites

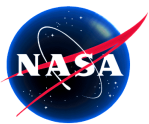


Preliminary Subsystem Technology Themes to Support Innovative Earth Science Measurements

NMP



- Large Aperture Lightweight Inflatable/Deployable/Optics/Antennas
 - Radiometers
 - Radars
 - Lidars
 - Imagers
- Ultra-high Rate Communications/Onboard Processing
 - High spatial/spectral resolution imaging
- Autonomous Constellation Control/Operation
 - Integrated network observatory
 - Coordinated observations at multiple location/vantage points.



Inflatable Microwave/Millimeter Antennas

NMP

Component Technologies

Space Inflatable Structures, (TRL 5)

- System architecture
- Deployment control
- Dynamic analysis and simulation
- Scaling laws and ground testing

Rigidization in Space, (TRL 4)

- Low or no power requirements
- Low or no contamination

Long-Term Space Survivability, (TRL 4)

- Materials characterization
- Degradation effects of space environment
- >5 year survivability

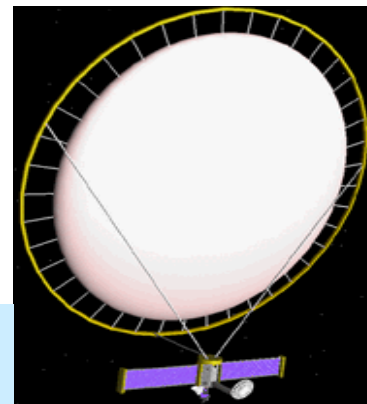
Membrane Compatible Electronics (TRL 3-4)

- Multi-layer RF membrane microstip array aperture
- (L-band, 80 MHz bandwidth, dual-polarization)
- High frequency membrane reflector and reflectarrays
- (Ku-band, Ka-band, W-band)
- MEMS T/R Module
- Thin-film solar array

0 g for
deployment
& performance

0 g,
Vacuum &
Extreme Temp

Radiation,
Atomic O &
Micrometeoroid



Measurement Approach

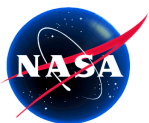
- Altimeter
- Scatterometer
- Synthetic Aperture Radar
- Rain Radar

Science Needs

- Soil Moisture & Ocean Salinity
- Carbon Cycle & Biomass Budget
- Topography & Natural Hazards
- Ocean Surface Wind & Topography
- Land Surface Water & Ice Sheet
- Monitoring
- Global Cloud Mapping &
- Precipitation

Missions

EOS 3,4,6,7,
EX 5,6



Ultra-high Data Rate Communications

NMP

Component Technologies

Acquisition, Tracking and Pointing

- Acquisition, tracking and pointing algorithms
- 1.55m FPAs
- Laser beacons
- Fast steering mirrors

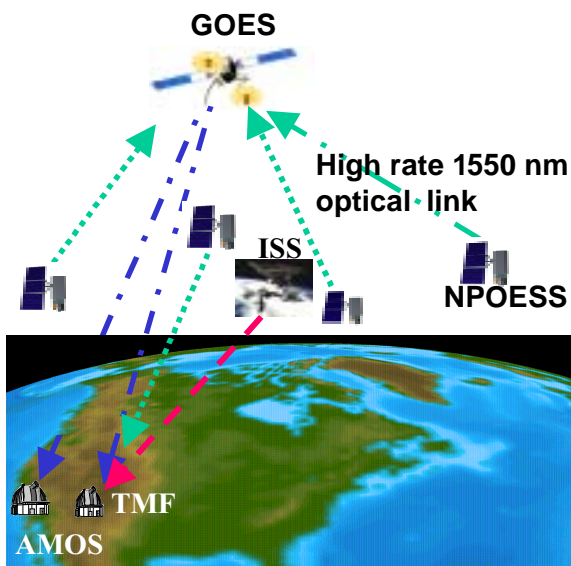
Optical Antennas

- Telescopes, thermally stable 0.1-0.3m aperture

Ultra-High Speed Communications

- Modulators 1-10 Gbps
- Lasers, 1.55m
- Multiplexers and demultiplexers
- Detectors, 1.55m high speed, low-noise

Precision pointing over long ranges



Supports system level demo from space

Measurement Approach

- Synthetic Aperture Radar
- Hyperspectral Imaging Fourier Transform
- Imaging Spectrometry

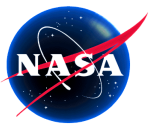
Science Needs

High Spatial Resolution:

- Hyperspectral Land Imaging
- Severe Storm Prediction
- Surface Hydrology & Precipitation
- Tectonic Hazard Prediction
- Ozone Monitoring

Missions

EX 6-7, EOS 8, NPOESS, Landsat 9, GIFTS, ...



Intelligent Distributed-Spacecraft Infrastructure

NMP

Component Technologies

Formation Flying

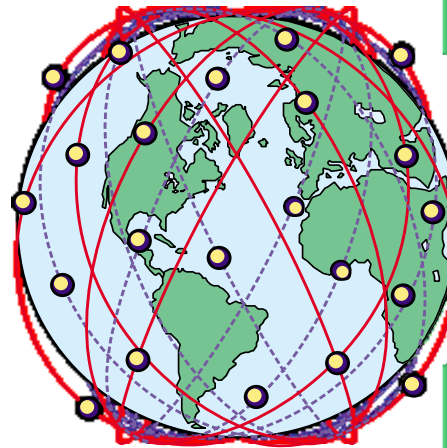
- Autonomous reconfiguration
- Virtual dynamical coupling
- Collision avoidance
- Optimal fuel strategy
- Orbit maintenance
- System modeling and coordination

High-precision measurements with large number of stand-alone instruments

Sensor/Satellite Networks

- Continuous communication coverage via asymmetric, hybrid links
- Management of a complex, multi-node heterogeneous network
- Scalable design for incremental network growth
- Graceful degradation to network performance during stress
- Robust routing, adaptive bandwidth allocation, and intelligent power control of nodes

Global-coverage scalable network for robust, on-demand, high-throughput data transfer



Measurement Approach

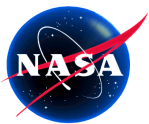
- Multiple Networked Orbiters
- Sensor Webs
- Smart Sensors

Science Needs

- Atmospheric Chemistry
- Temperature, Clouds & Radiation Budget
- Global Precipitation
- Hazard Monitoring
- Diurnal Vegetation Monitoring

Missions

EOS 1,3,5,6,7,9
OP 3,6



Augment NMP Program Content with Enabling Breakthrough Subsystem Perspective

NMP

- **Balanced mix of of subsystem/integrated measurement systems**

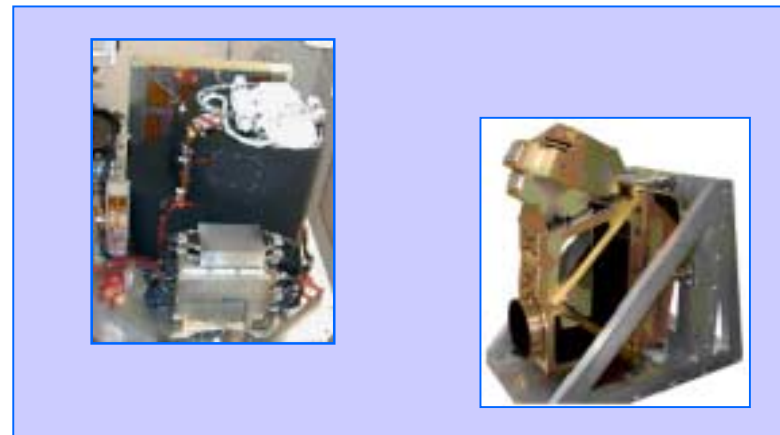
Breakthrough Subsystems



- Breakthrough subsystems that
 - Require flight validation (environment, paradigm shift)
 - Enable critical functions for key/enhanced measurements
 - Yield broad benefits to multiple measurement systems
- Breakthrough subsystems can be tested as stand-alone items without full instruments
 - More cost effective
 - Focus on validating technologies where needed

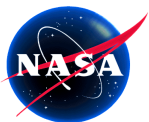
Augmentation to include validation of breakthrough subsystems

Integrated Measurement System



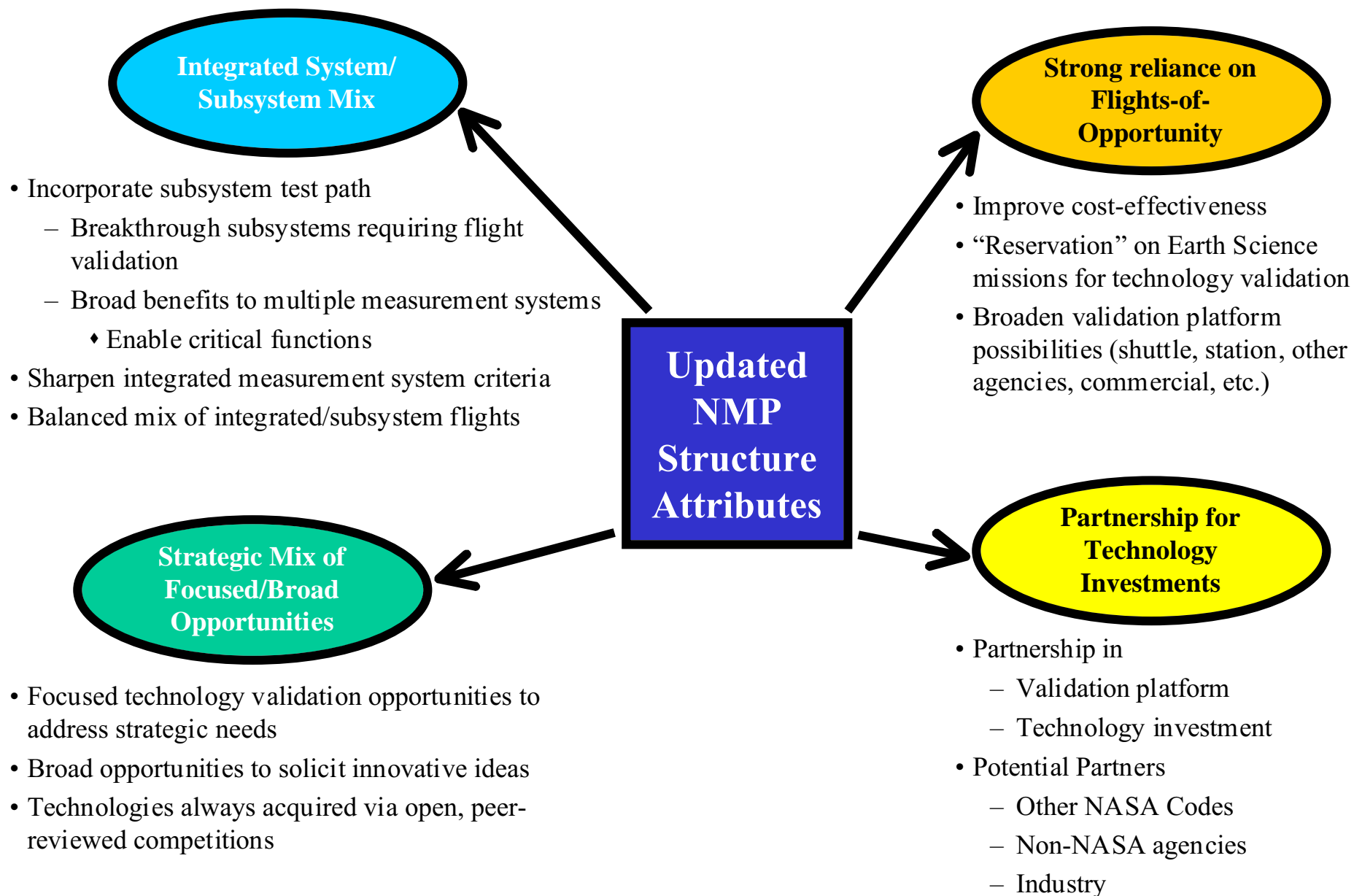
- Ensure critical science measurement continuity
- Required risk reduction for transition to operational measurements
 - Fundamental paradigm shift in measurement approach

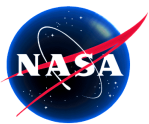
Sharpen Current NMP Criteria



Updated New Millennium Program Attributes

NMP

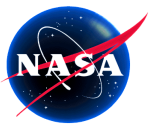




Summary/Recommended Next Steps

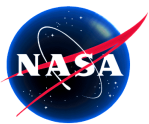


- Initiated identification of technology validation needs for Earth Science
- Examined updated program structure
 - Improve cost effectiveness
 - Mix of breakthrough subsystem/innovative measurement system
 - Enhanced partnership
- Recommended next steps
 - Assess breakthrough subsystem validation requirements/approaches
 - ◊ Conduct mini-workshops on technology validation need (3 or 4 focused areas)
 - ◊ Status review/feedback sessions with YS/YO in late March'00
 - ◊ Presentation in April '00 to Code Y/AA
 - Synthesize technology investment advocacy package



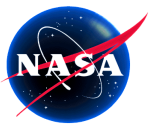
- **One day workshop**
 - A. Large, light weight Microwave/Millimeter Antennas
 - B. Ultra-High Data Rate Communication
 - C. Intelligent Distributed - Spacecraft Infrastructure
 - D. High Performance Spectrometry
 - E. Light Weight Deployable UV/Visible/IR Telescope
- **Purpose: To develop technology validation experiment/development plan for specific technology areas to address OES science and application needs**
- **Discuss: - Technology requirements from science measurements perspective**
 - Technology development plan (5-10 yr. planning horizon)
 - What is the right space validation experiment
- **Will invite, with HQ concurrence for each workshop**
 - 5 Scientists*
 - 5 Technologists
 - 2 Co-Chairs (Science & Technology)
 - 1 Facilitator

* Code YS Discipline Scientists to be invited to each workshop
- **Week of April 3 - 7 or before (goal of three workshops completed this week, balance by 4/19)**



- **One day workshop**
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A. Large, Light-Weight Deployable Antennas

Co-Chairs

- Science: **T. England** (U of M)
- Technology: **C. Moore** (LaRC)
- Workshop Facilitator: **D. Crisp** (NMP)

Location: **JPL**, Date: **4/13/00**

Scientists

Technologists

John Huang
Michael Lou

B. Ultra-High Data Communication

Co-Chairs

- Science: **A. Goetz** (U of C)
- Technology: **K. Bhasin** (Glen)
- Workshop Facilitator: **F. Lansing** (NMP)

Location: **GSFC**, Date: **4/7/00**

Scientists

Martha Maiden
Tim Berkoff
James Dodge
Rob Green
Bob Murphy

Technologists

Hamid Hemmati
Godfrey Anzic?
Dennis Andrucyk
Phil Luers
Greg Prescott?

C. Intelligent Distributed - Spacecraft Infrastructure

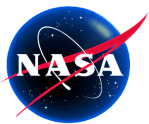
Co-Chairs

- Science: **G. North**
- Technology: **W. Kaiser** (UCLA)
- Workshop Facilitator: **C. Raymond** (NMP)

Location: **GSFC**, Date: **4/6-8/00**

Scientists

Technologists



D. High Performance Spectrometry

Co-Chairs

- Science: **D. Wickland**
- Technology: **TBD**

Workshop Facilitator: **C. Stevens**

Location: **JPL**

Dar Roberts (UCSB)

Roger Clark (USGS)

Joe Boardman (AIG)

Laurie Richardson (FIU)

Susan Ustin (UCD)

Greg Asner (Uof C)

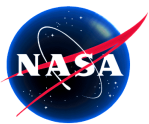
E. Light Weight Deployable UV/Visible/IR Telescope

Co-Chairs

- Science: **TBD**
- Technology: **F. Peri**

Workshop Facilitator: **V. Sarohia**

Location: **LaRC**



*DRAFT
TEMPLATE*

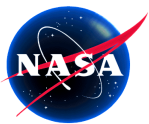
**TITLE OF
TECHNOLOGY/BREAKTHROUGH CAPABILITY**

Description of
Technology

Technology
Picture(s)

Relevance/Importance
to Future Code Y
Missions

Measurements & Requirements
“View of the Scientists”



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TEMPLATE*



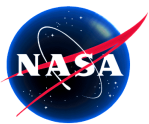
**TITLE OF
TECHNOLOGY/BREAKTHROUGH CAPABILITY**

Description of the SOA
of the Technology

Picture Showing Current
Technology Products and/or
Ground Test Models

Major Technology
Elements and Current
TRL

Technology Development
Roadmap Showing Space
Validation Flight(s) as Key
Milestones



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TEMPLATE*

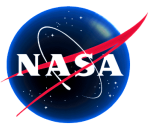
**TITLE OF
TECHNOLOGY/BREAKTHROUGH CAPABILITY**

Description of the Proposed Space
Validation and Justification for
Validation in Space

Expected Benefits, Including
Enabled Measurements and
Missions, Enabled Critical
Functionality, and/or Expected
Life-Cycle Cost Reduction

Projected Cost and
WF Requirements
By FY

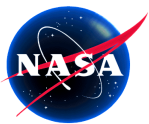
Top-Level Development
and Flight Schedule



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THE SPACE VALIDATION EXPERIMENT(S)

**What is the “Right” Space Experiment
(Consensus of the Science and Technology Communities)**



THE NMP PERFORMANCE METRICS

- ★ Each project selected for formulation shall respond to at least one technology requirement for more than one mission in the Earth Science or Space Science Enterprise Strategic Plan.
- ★ The selection of the destination for each flight validation project shall be determined based upon the requirements for technology validation and not be driven by requirements for science data collection.
- ★ Technologies eligible for selection for a new project shall have completed technology development to a technology readiness level where the concept design has been tested experimentally.
- ★ Technologies selected for a project shall have completed testing of the pre-prototype prior to project approval and initiating project implementation
- ★ Over a five-year running time period, a minimum of 80 percent of the approved project-defining technologies shall be flight validated, and 100 percent of the project-defining technologies that are launched in a project shall be flight validated.
- ★ Over a five-year running time period, a minimum of 70 percent of the approved project-enhancing technologies shall be flight validated.
- ★ Advances in technology development that occur prior to launch shall be documented in annual updates to the NASA Technology Inventory and in a report prepared and submitted by the NMP Office to the applicable Enterprise as part of the annual budget review.
- ★ Data from technology flight validations shall be documented and made available to technology providers and mission planners within six months of the completion of flight validation subject to the restrictions imposed by Export Administration Regulations and International Traffic in Arms Regulations.